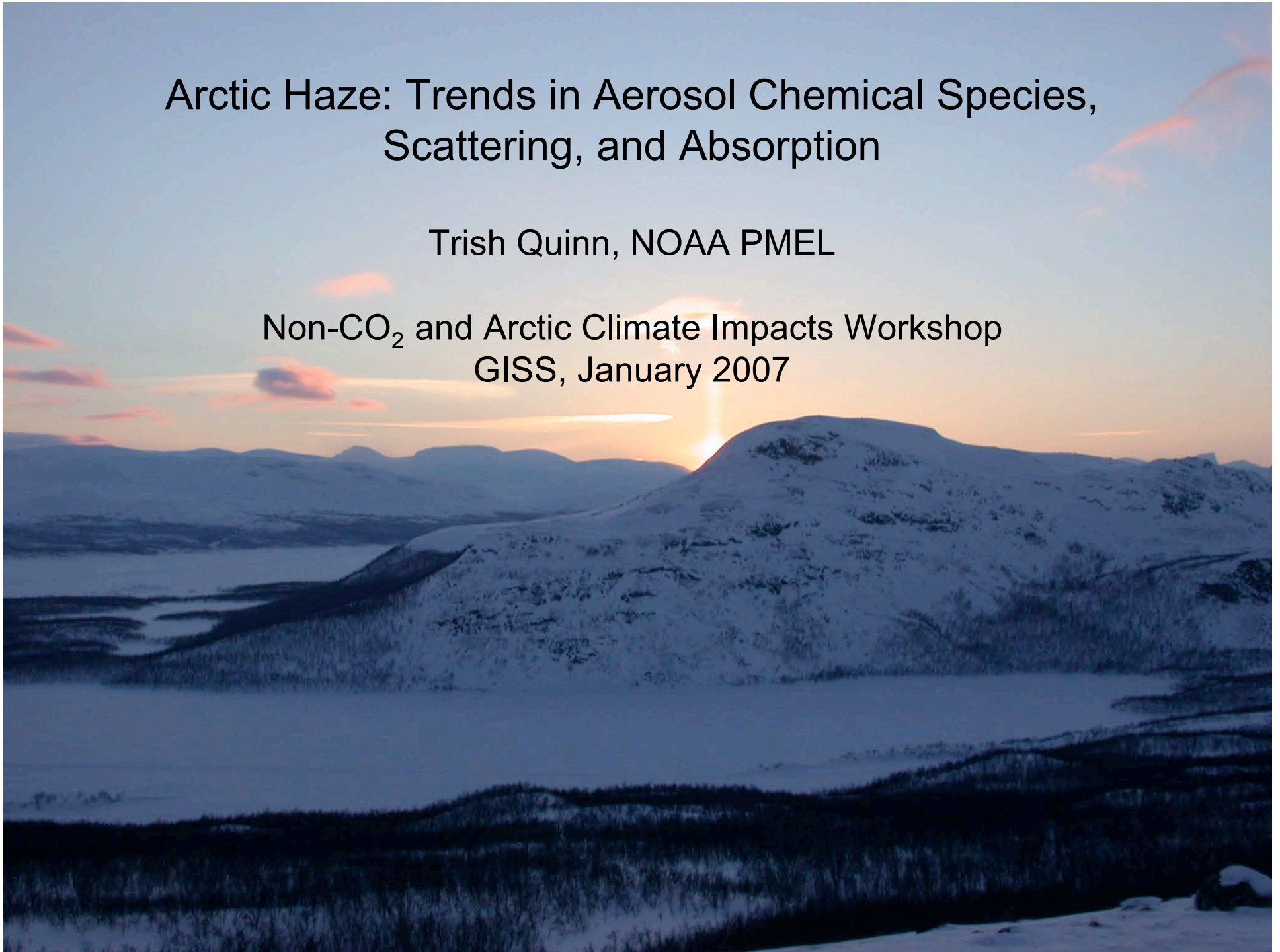


Arctic Haze: Trends in Aerosol Chemical Species, Scattering, and Absorption

Trish Quinn, NOAA PMEL

Non-CO₂ and Arctic Climate Impacts Workshop
GISS, January 2007



Potential Impacts of Arctic Haze

- **Visibility degradation**
- **Source of contaminants to Arctic Ecosystems**
- **Perturbation of the short and longwave radiation balance in the Arctic**



Mean position of the Arctic air mass in winter (January) and summer (July)



Mean position of the Arctic air mass in winter (January) and summer (July)

Winter/Early Spring

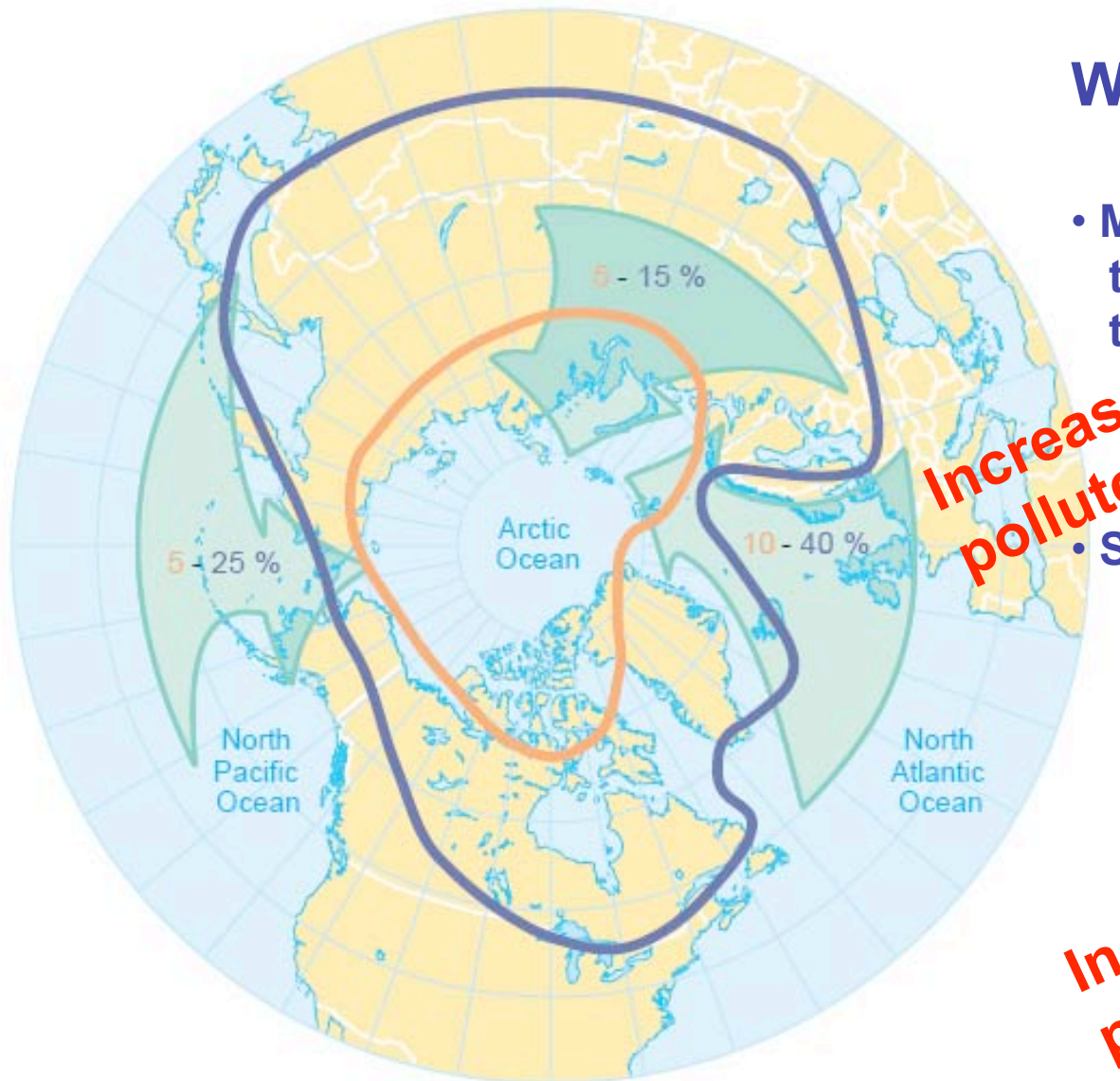
- Meridional transport from the mid-latitudes to the Arctic intensifies

- Set up of surface-based temperature inversion which inhibits:

- mixing between atmospheric layers
- formation of clouds and precipitation

Increased transport from polluted mid-latitude regions

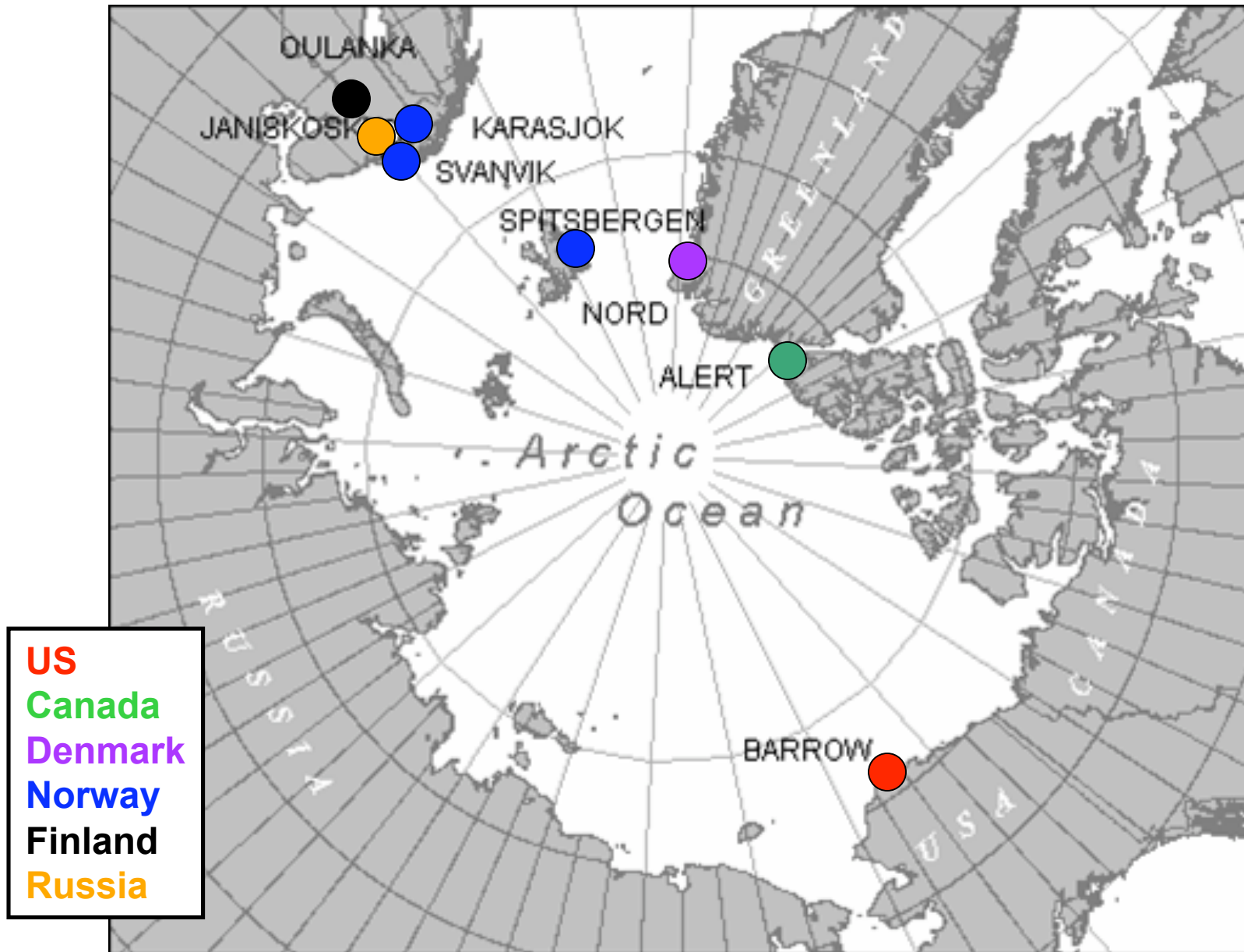
Increased lifetime of pollutants



— Arctic Front Winter
— Arctic Front Summer

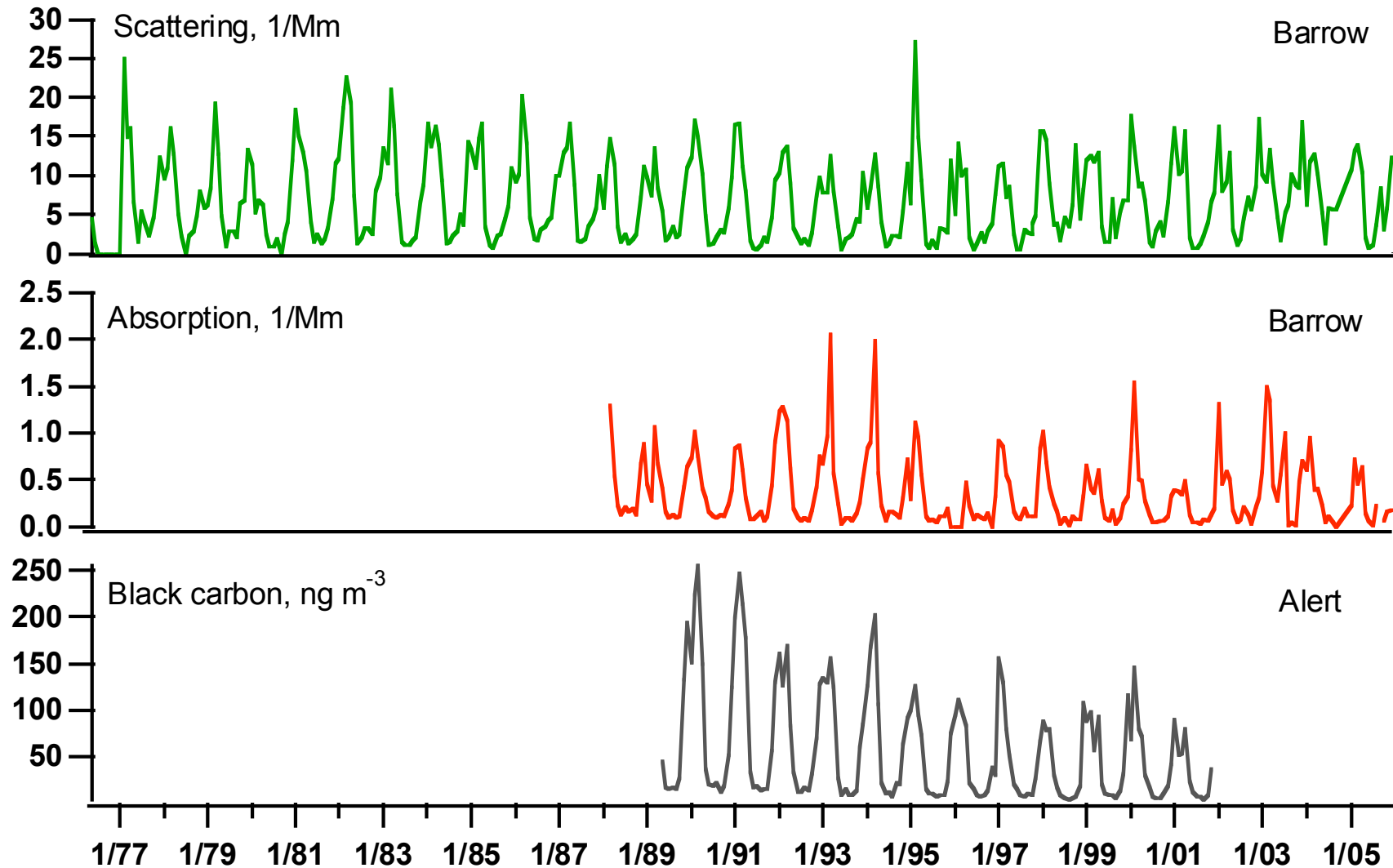
➤ Major south to north air transport routes into the Arctic

Locations of Long-term Arctic Monitoring Stations



Seasonality of Arctic Haze

Winter/Spring Increase in Aerosol Light Scattering and Absorption

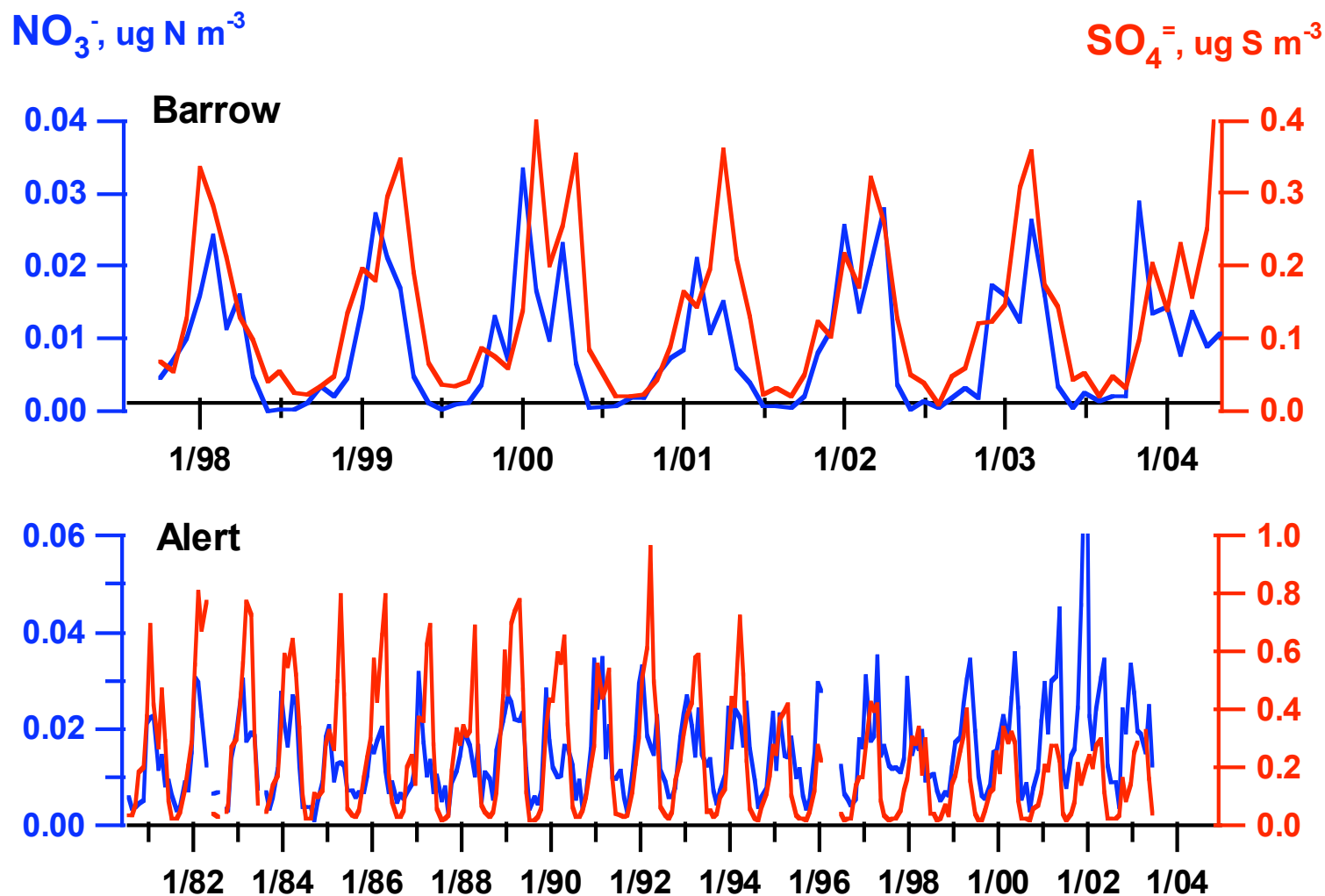


Monthly averaged values

Quinn et al., *Tellus*, 2006.

Seasonality of Arctic Haze

Winter/Spring Increase in Aerosol Nitrate and Sulfate

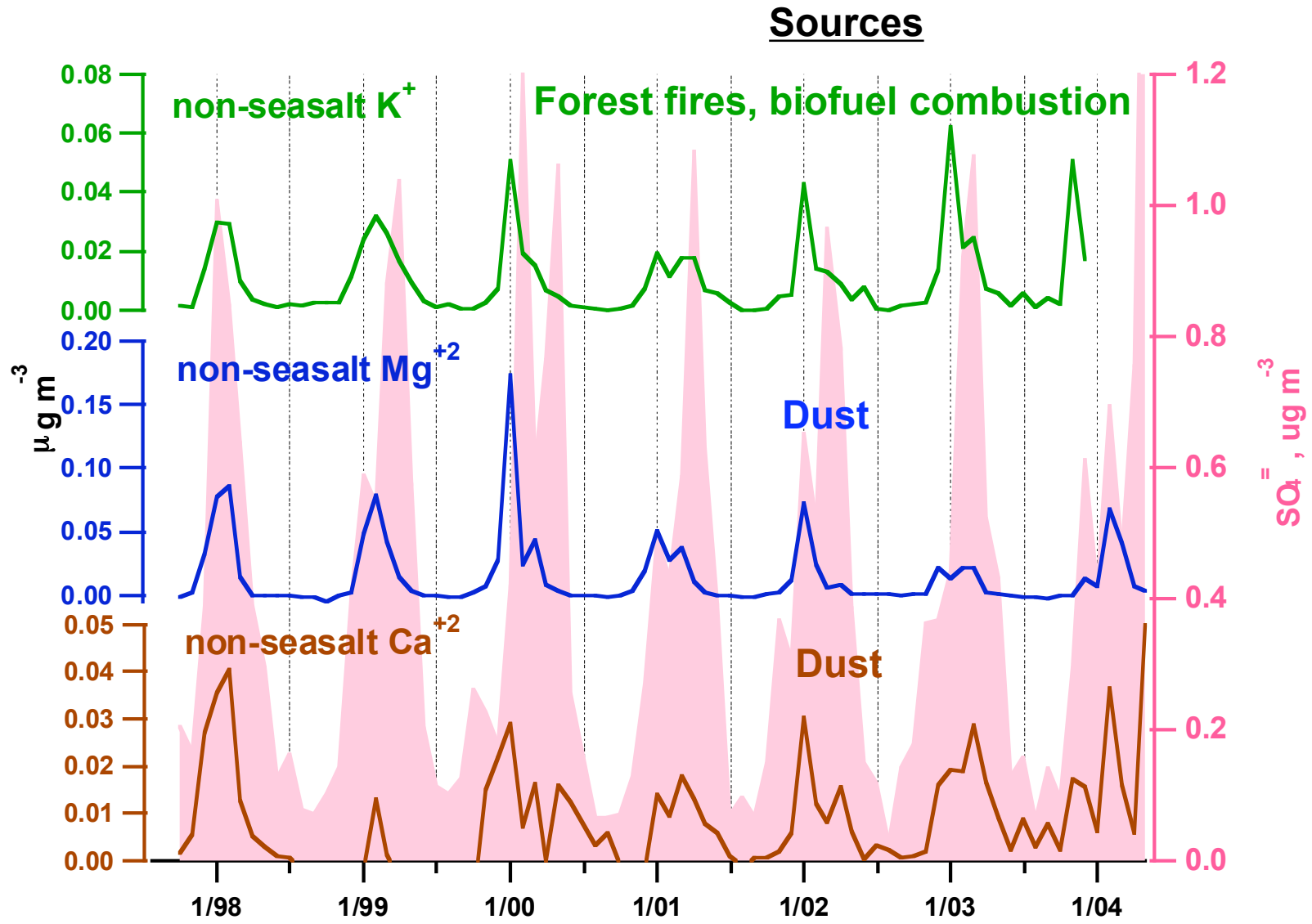


Sources: Diesel and gasoline engines
Fertilizer

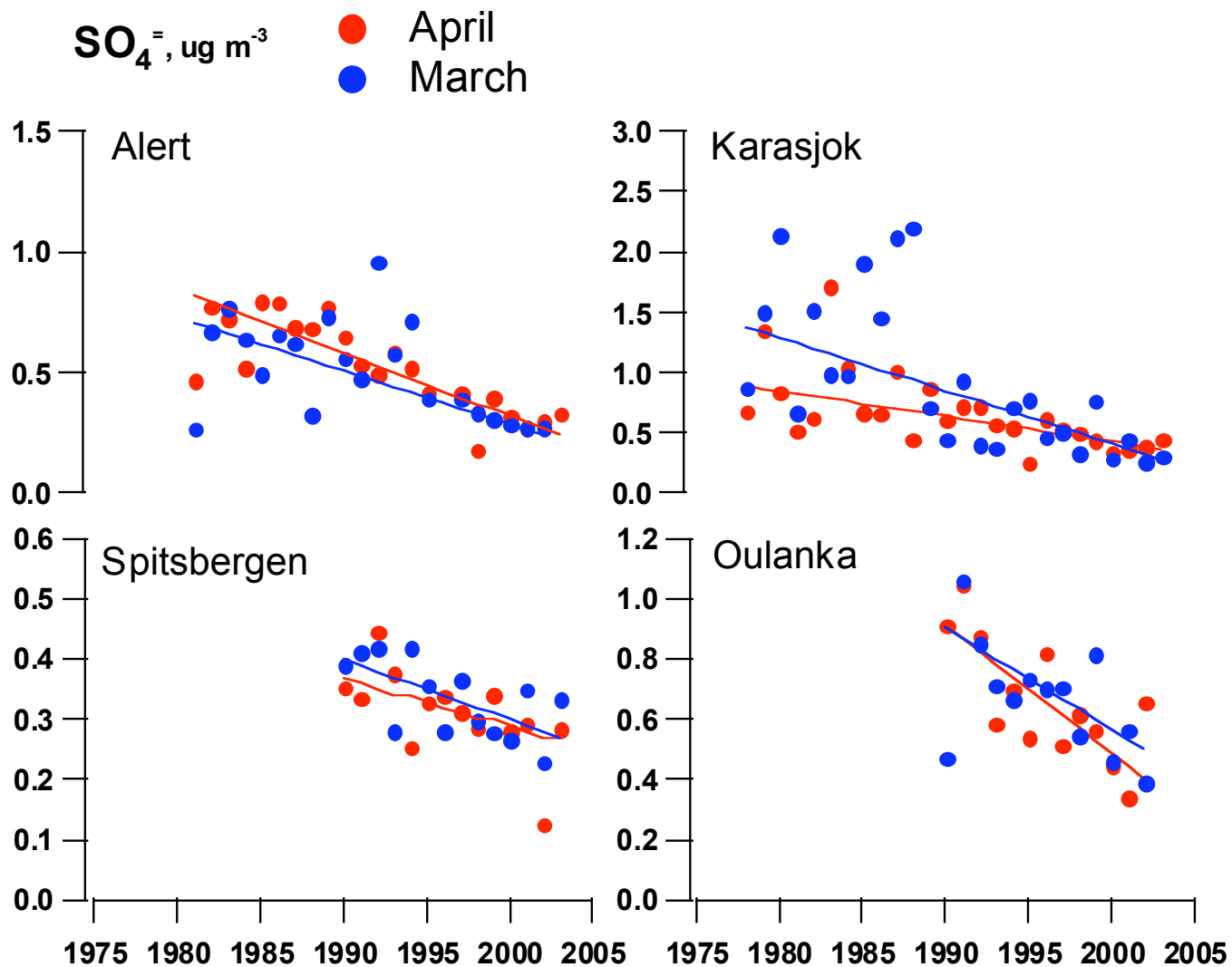
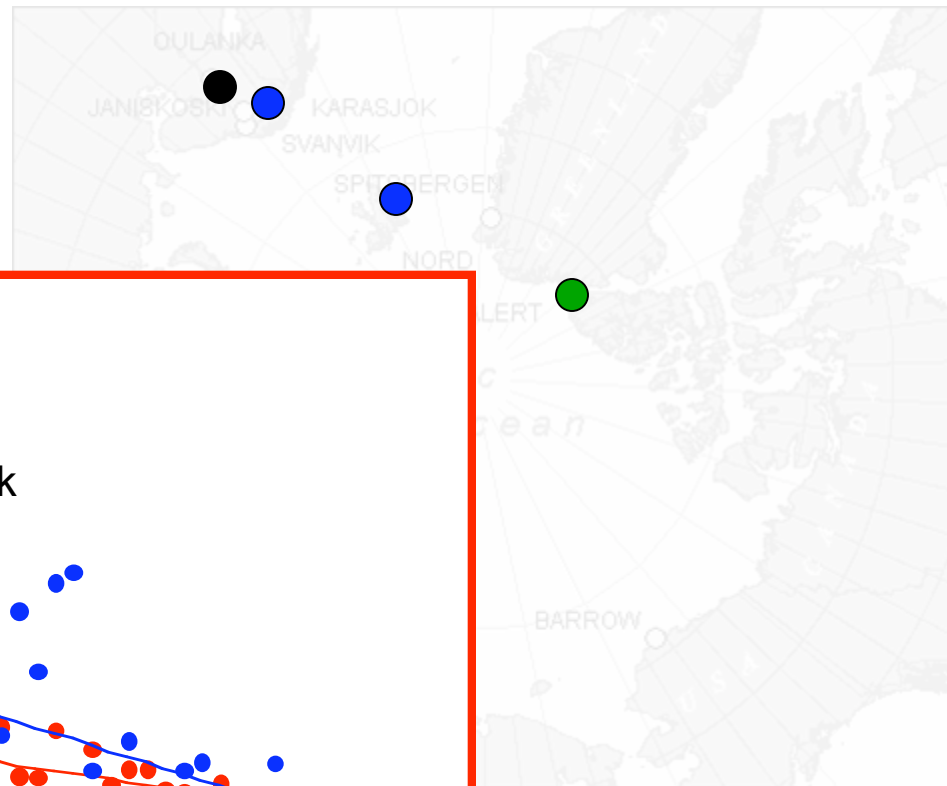
Coal fired power plants

Seasonality of Arctic Haze

Winter/Spring Increase in Aerosol Potassium, Magnesium, and Calcium



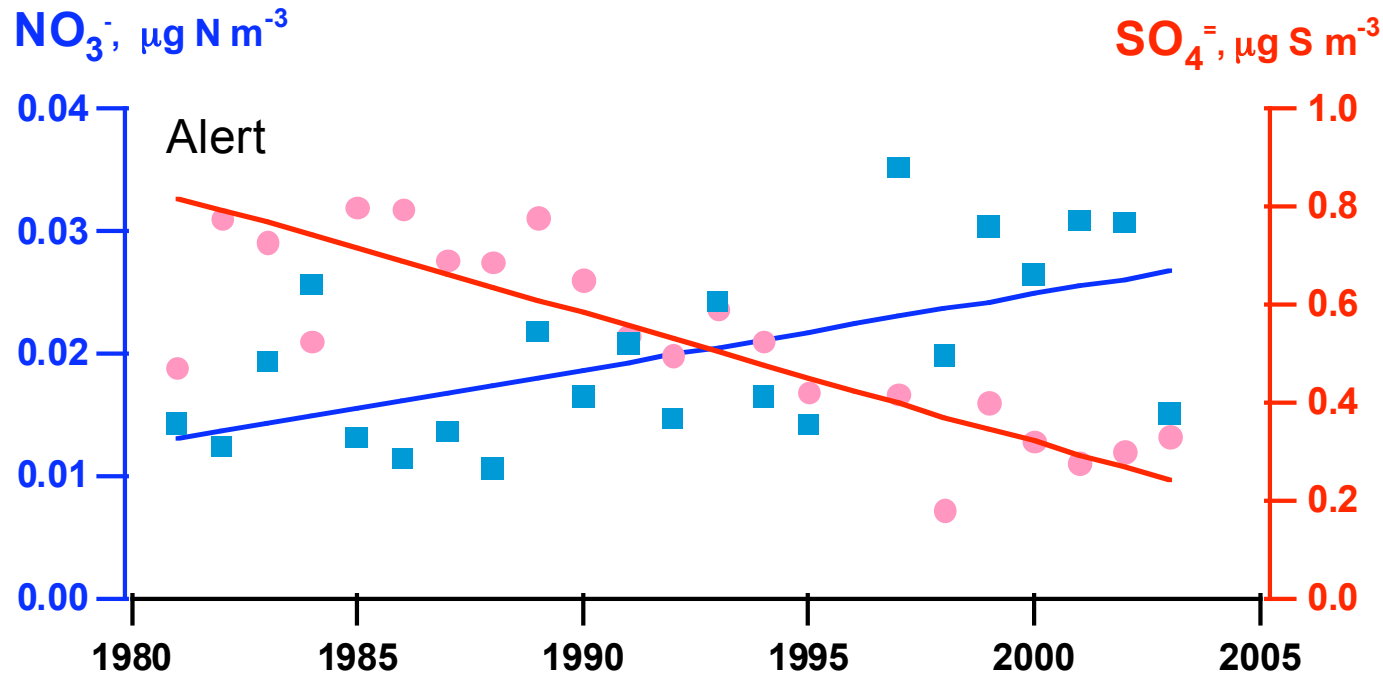
Detected Trends in Sulfate 1978 – 2004 (Monthly averages for March and April)



Quinn et al.,
Tellus, 2006.

Contrasting Long Term Trends in Nitrate and Sulfate at Alert

Monthly Averages for April



Sources: **Diesel and gasoline engines**
Fertilizer

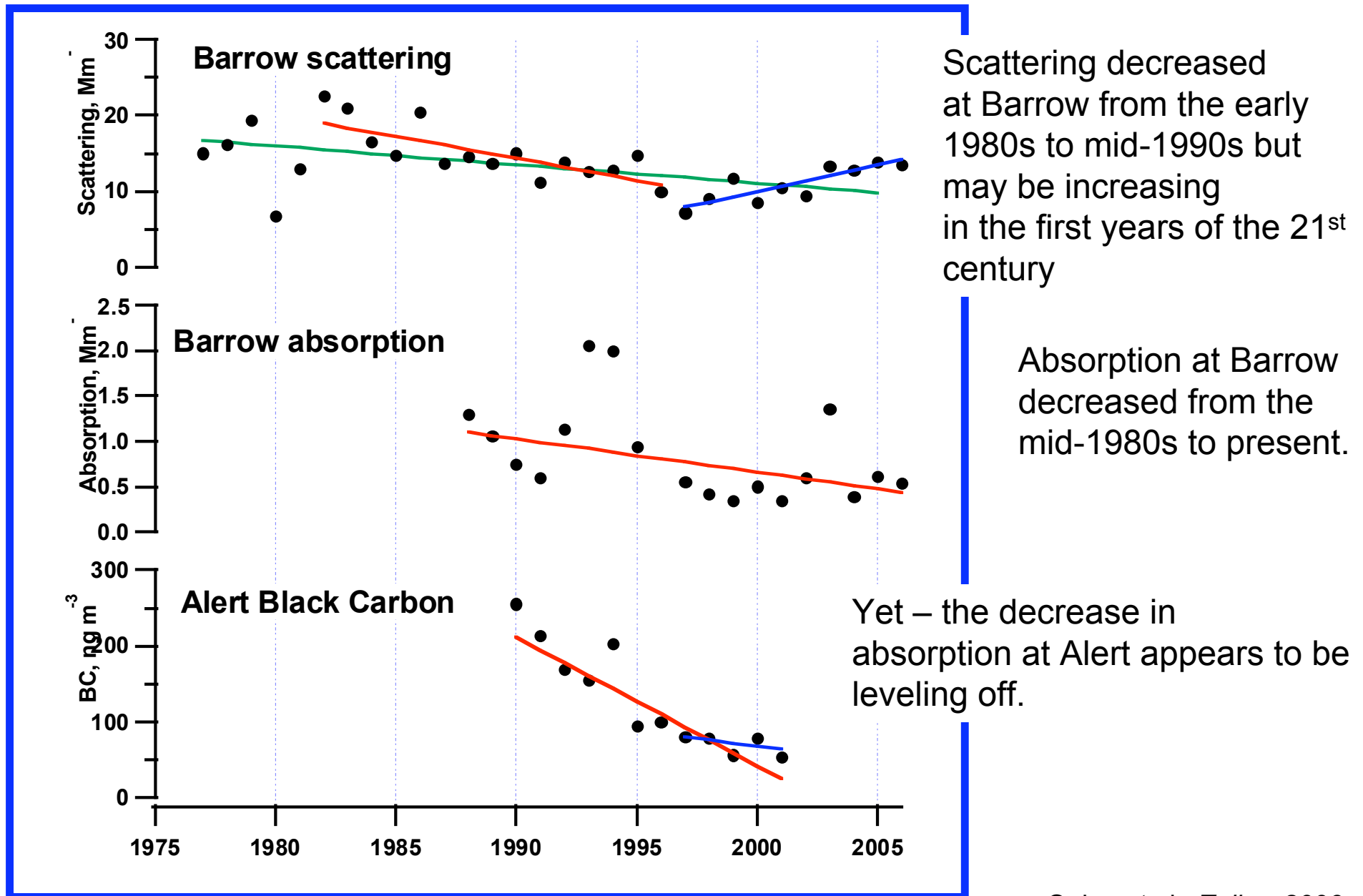
Coal fired power plants

Trend in organic aerosol concentration
is unknown due to a lack of data.

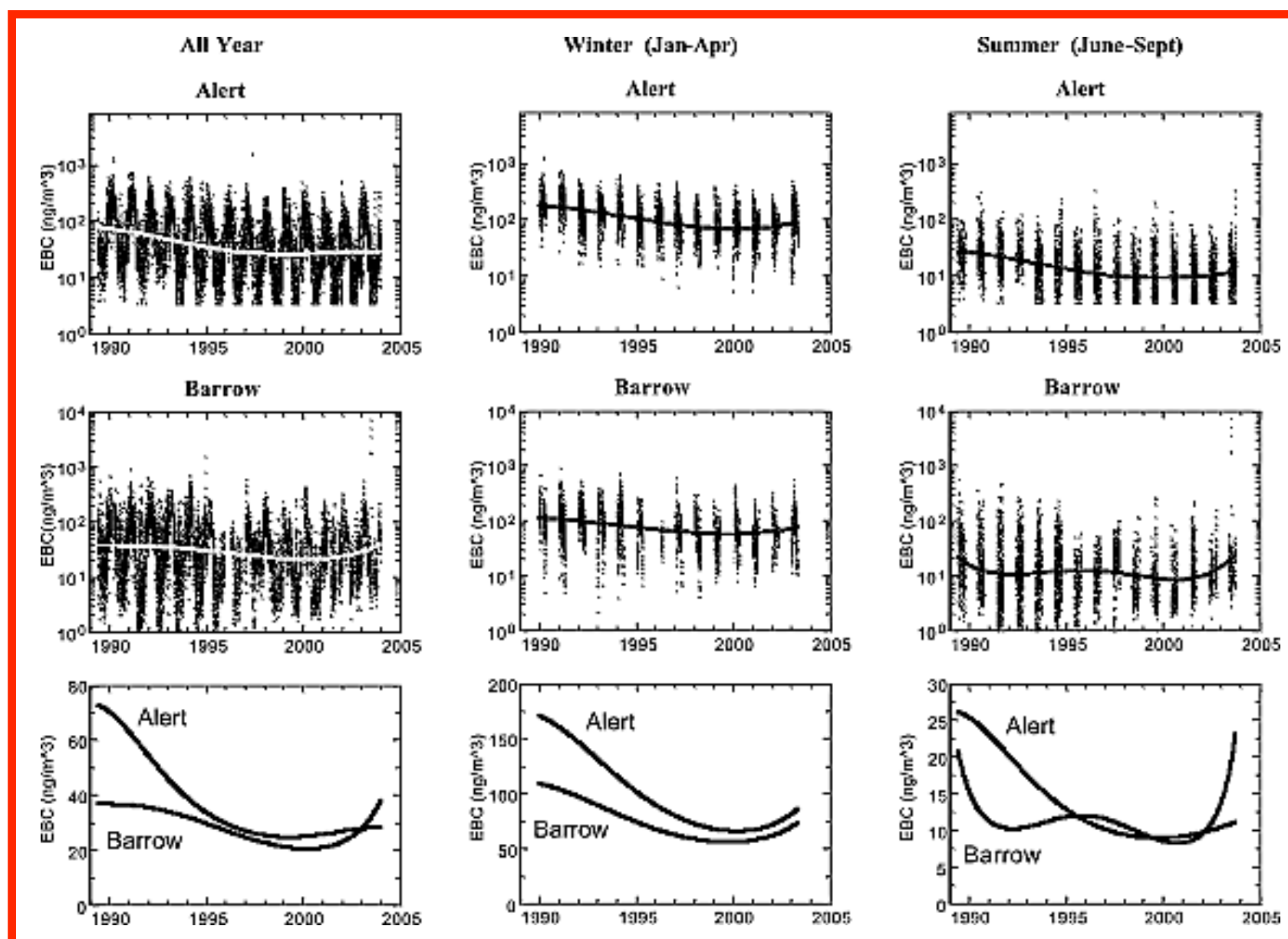
Quinn et al., *Tellus*, 2006.

Trends in Aerosol Light Scattering and Absorption at Barrow and Alert

Monthly Averages for March



Long Term Trends in Black Carbon at Alert and Barrow



“At both sites, the EBC concentrations show signs of an increase starting in 2000 – 2001.”

Sharma et al., *JGR*, 2006

ISSUE: Levels of Black Carbon and NO_3^- Appear to be Increasing in the Arctic

Potential Contributing Factors

- Transport pathways are changing
- Loss pathways (deposition) are changing
- Sources are changing and/or emissions are increasing
 - **What are the source regions?**

Southern Asia

Koch and Hansen (JGR, 2004): Using a general circulation model suggested that one of the major source regions of Arctic soot today is southern Asia.

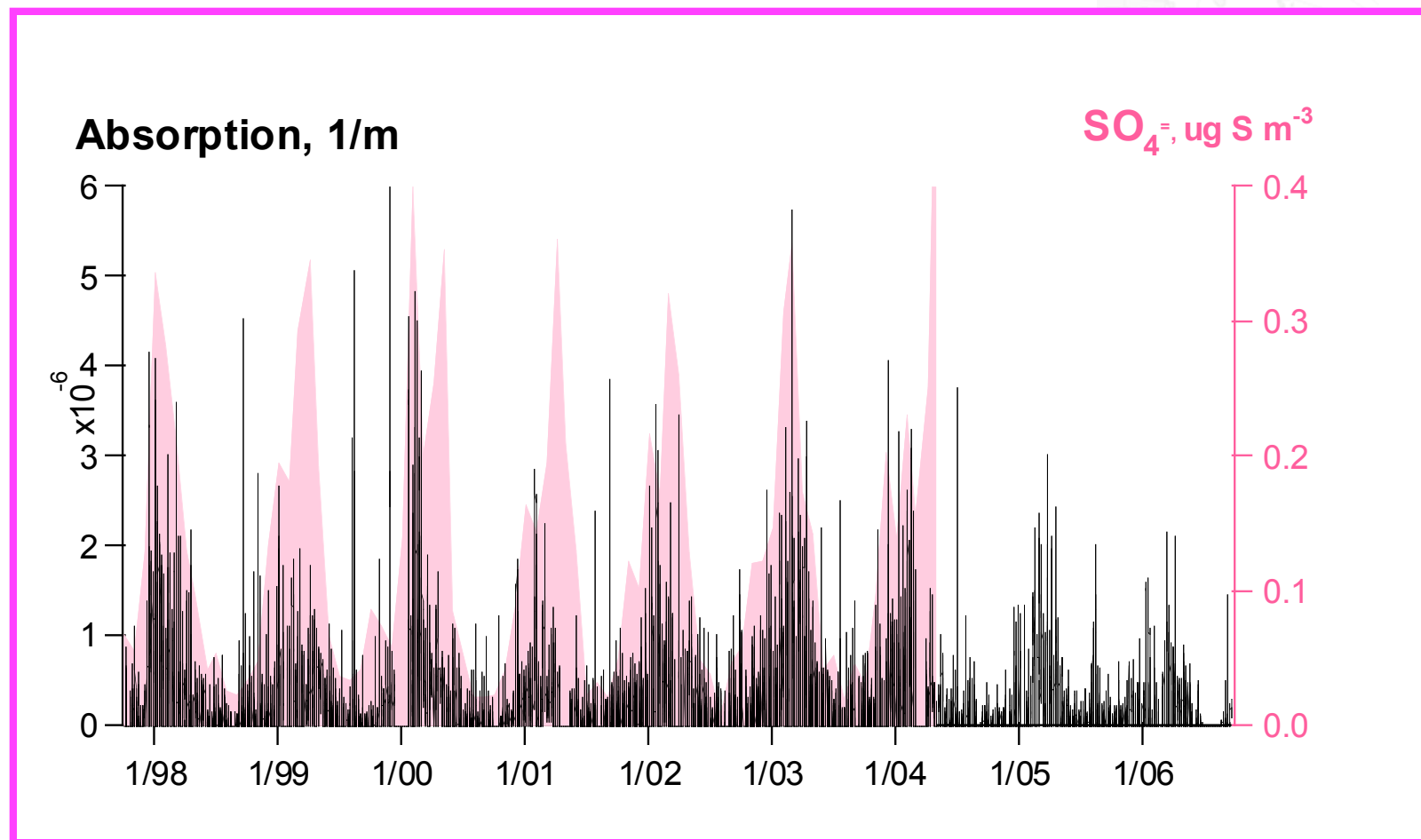
Northern Europe and Asia

Stohl (JGR, 2006): Refuted this finding based on the long passage from pollution source regions in south and east Asia to the Arctic relative to more rapid transport from Europe and northern Asia.

Boreal and temperate forests

Stohl (JGR, 2006): Identified boreal and temperate forest fires as a significant source of black carbon during the summer.

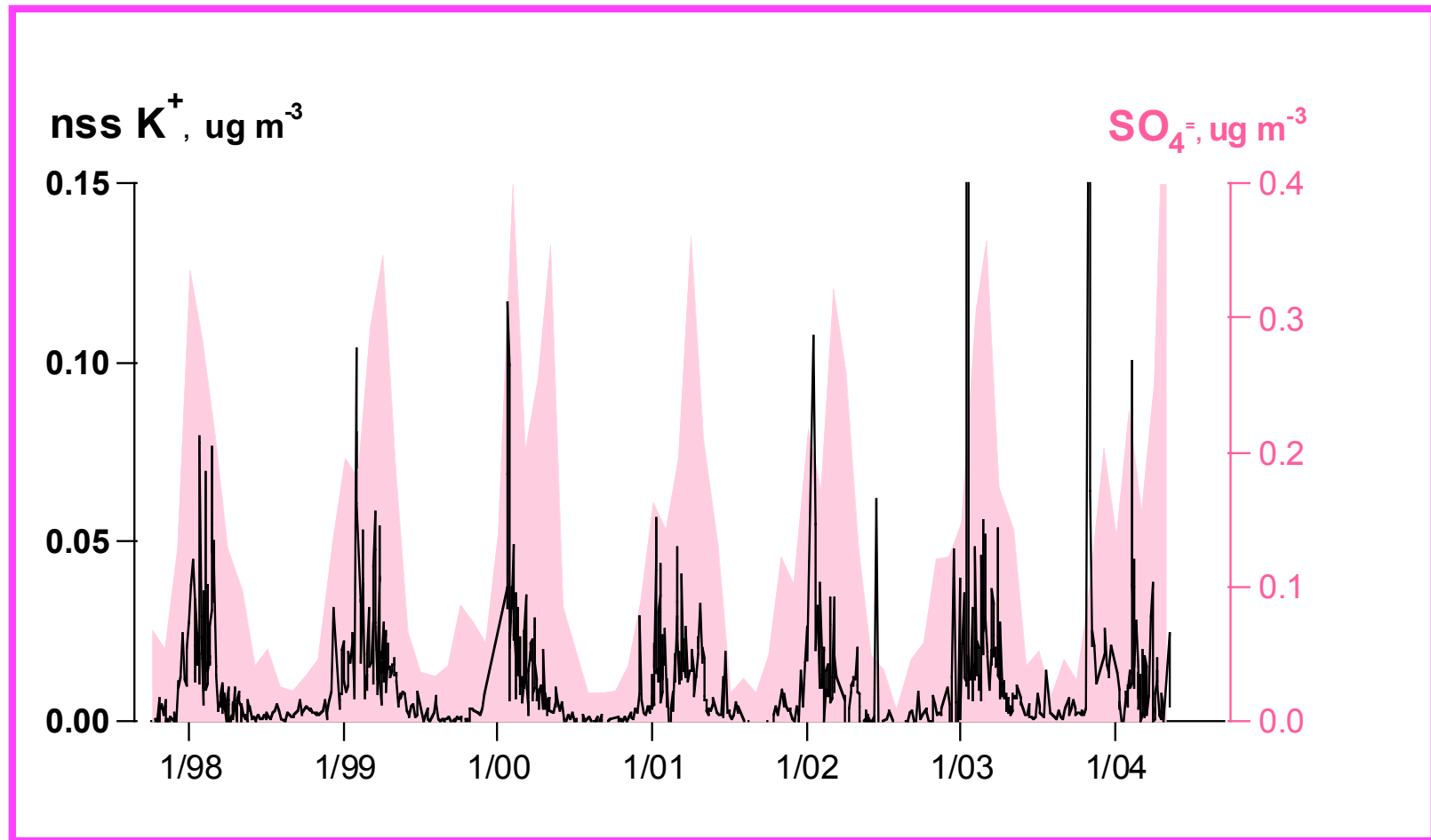
Absorption at Barrow (Hourly Data) Compared with Sulfate



Seasonal maximum in absorption corresponds to timing of Arctic Haze
but.... there are spikes during the summertime as well.

◇ Similar results for Alert

Non-sea salt K^+ at Barrow (Daily Data) Compared with Sulfate
(Tracer of biomass and biofuel burning.)



Similarly, the seasonal maximum in K^+ corresponds to timing of Arctic Haze

Based on these data that were collected at low altitude, coastal sites:

- **Both Arctic Haze and forest fire sources are episodic in nature**
- **Highest concentrations of black carbon in the lowest level of the atmosphere occur during the Arctic Haze season**

However there is evidence of:

- **Injection of smoke from forest fires to the upper atmosphere (e.g., Fromm et al. *JGR*, 2005)**
- **Biomass burning signatures in snow at the high altitude site of Summit, Greenland (e.g., Dibb et al., *Atm. Env.*, 1996)**

Two Issues affecting the climate impact of soot deposited to the surface:
Seasonality of the soot source and transport to the Arctic
Seasonality of deposition and ice/snow melt for low vs. high altitude sites

What does this research reveal about the pollutants reaching the Arctic that is relevant to Arctic Climate?

- **Levels of sulfate are decreasing at many sites in the Arctic**
- **Levels of black carbon and nitrate appear to be increasing**
- **Concentrations of black carbon are highest in the lowest level of the Arctic atmosphere during the Arctic haze season**
- **Will this change if the frequency and intensity of such fires increases?**
- **Climate Impacts of black carbon through deposition depend on:**
 - **the sources of the black carbon because they are seasonal**
 - **where it is deposited due to timing of the snow / ice melt**

What are the limitations of the research?

What additional research is needed?

- **Lack of long term measurements of atmospheric black carbon in the Arctic.** Such measurements are critical to understanding sources, transport pathways, and deposition losses. Long term measurements also help to improve existing climate and deposition models.

◇ Implement black carbon (absorption) measurements at more sites, particularly in the eastern Arctic.

◇ Implement measurements of trace elements at several sites in the Arctic for enhanced source information.

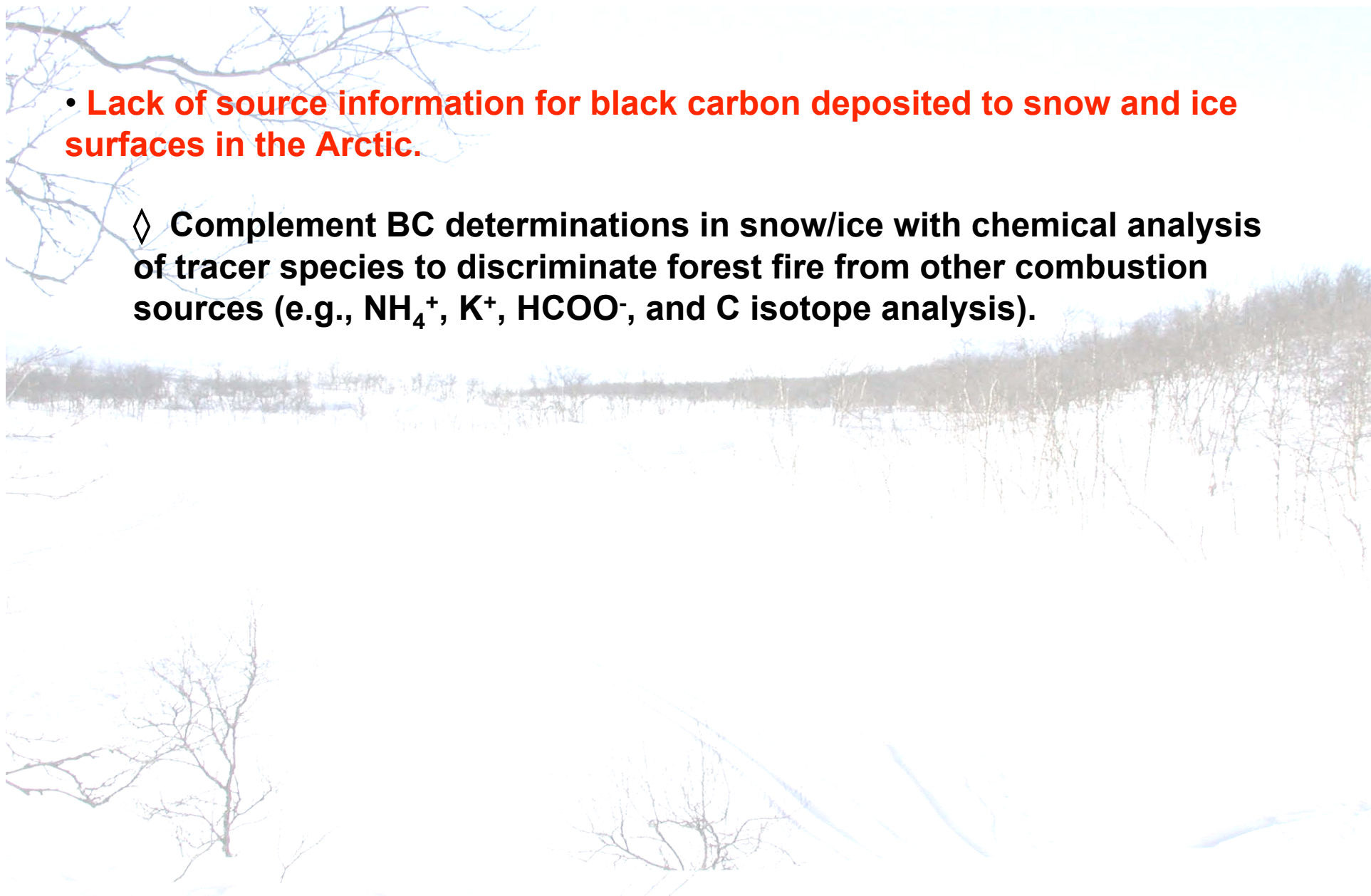
◇ Coordination of North American, European, and Russian monitoring networks and data bases

What are the limitations of the research?

What additional research is needed?

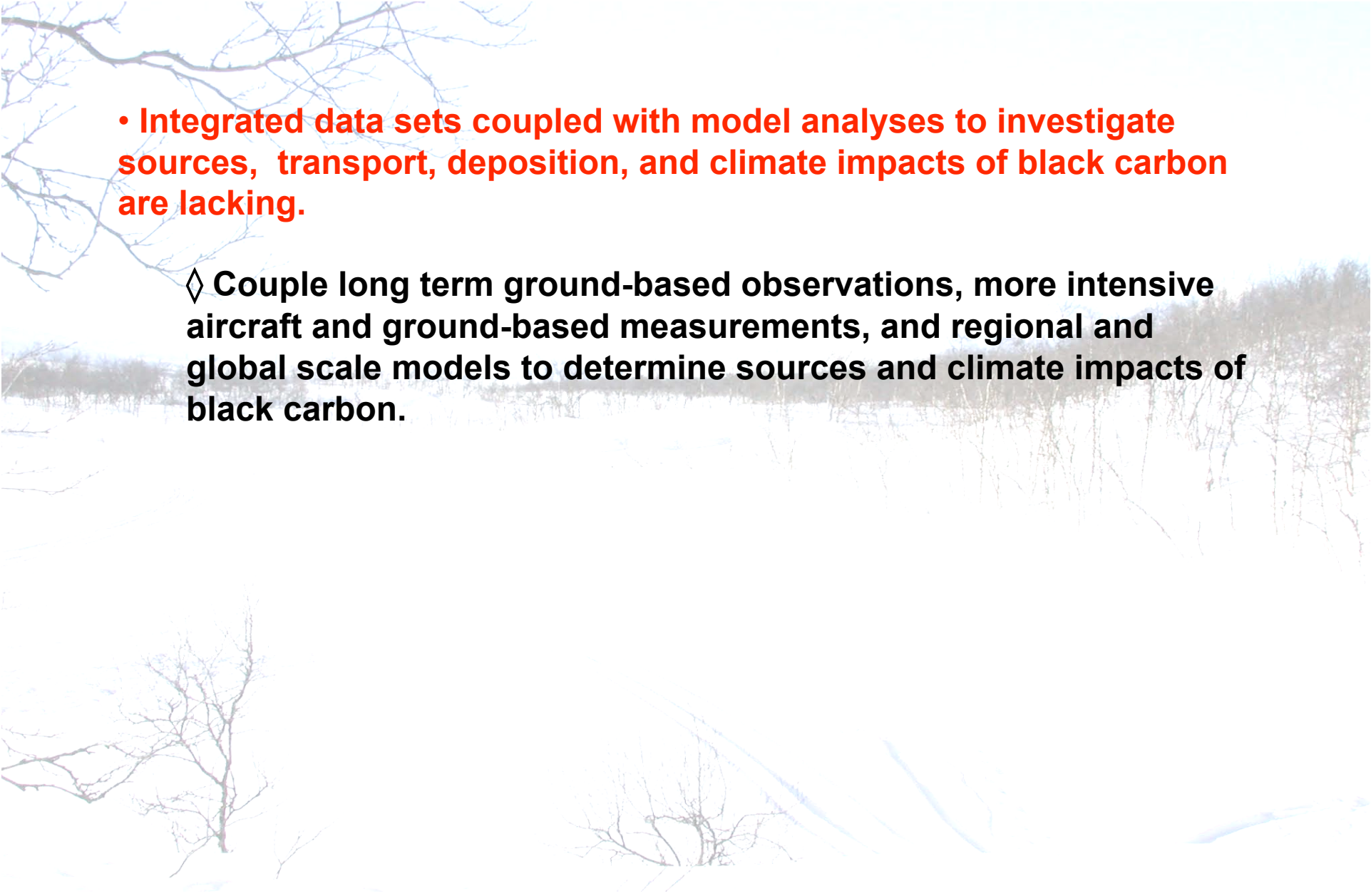
- **Lack of source information for black carbon deposited to snow and ice surfaces in the Arctic.**

◇ **Complement BC determinations in snow/ice with chemical analysis of tracer species to discriminate forest fire from other combustion sources (e.g., NH_4^+ , K^+ , HCOO^- , and C isotope analysis).**



What are the limitations of the research?

What additional research is needed ?



- **Integrated data sets coupled with model analyses to investigate sources, transport, deposition, and climate impacts of black carbon are lacking.**

- ◊ **Couple long term ground-based observations, more intensive aircraft and ground-based measurements, and regional and global scale models to determine sources and climate impacts of black carbon.**

What are the limitations of the research?

What additional research is needed ?



- **Organic carbon is a wild card at this point.** Trends, sources, composition, and climate impacts are uncertain. Yet particulate organic carbon may affect cloud microphysics and resulting radiative properties.

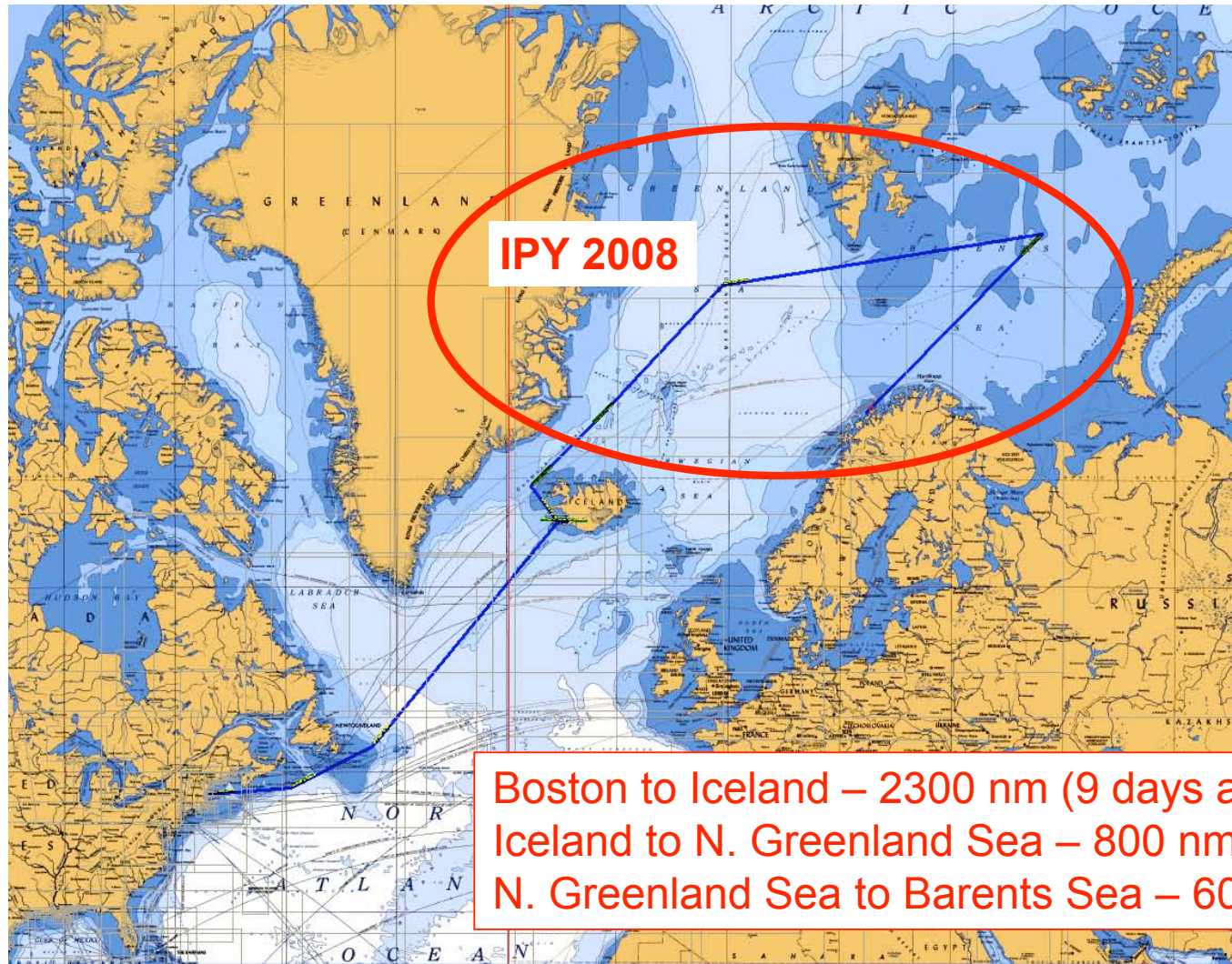
- ◊ Automated (long-term) measurements at ground-based sites are difficult but would be highly beneficial.

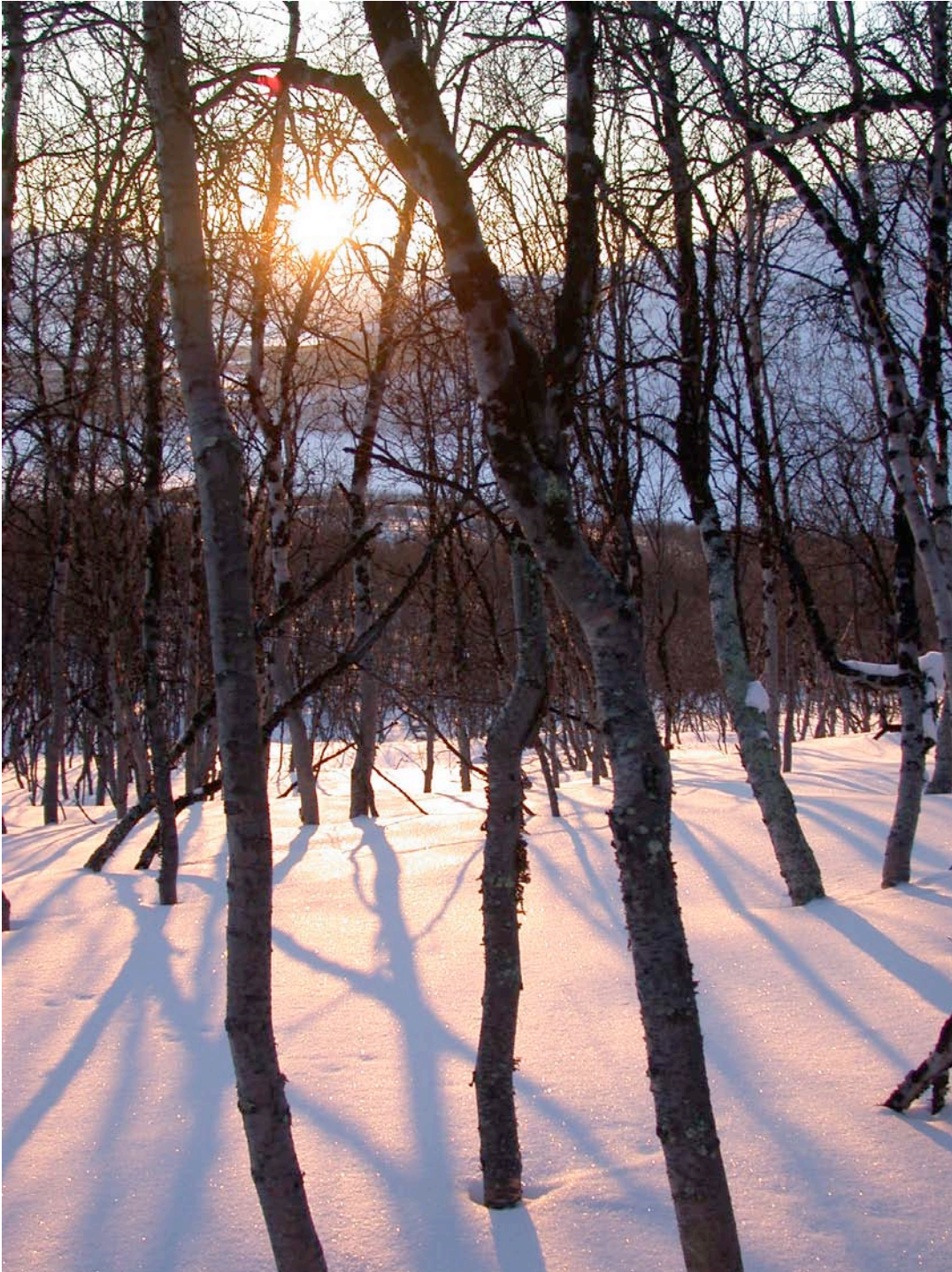
- ◊ Measurements of particulate organic carbon should be implemented during airborne and ground-based intensive experiments.

Proposed NOAA 2008 Field Study

International Polar Year Climate Study

March – April, 2008





Thanks to:

**NOAA's Climate Program Office
and Arctic Research Office**

**Members of the AMAP working
group on Acidifying Pollutants,
Arctic Haze, and Acidification in
the Arctic**